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SUPPLEMENTARY STUDIES ON THE DIFFERENTIAL MORTALITY WITH RESPECT TO SEED WEIGHT IN THE GERMINATION OF GARDEN BEANS—II

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Comparison of Means

Take first the most stringent comparison—that between the constants of the seeds germinating normally and those of the seeds failing to germinate, *A–C*. The frequencies and mean magnitudes are:

	f	Absolute Values	Relative Values
Plus differences	29	+.396	+3.50
Minus differences	21	−.702	−4.62
All differences	50	−.065	+0.09

Or considering only differences which are at least 2.5 times their probable error:

	f	Absolute Values	Relative Values
Plus differences	15	+0.541	+5.42
Minus differences	9	−1.355	−8.84
All differences	24	−0.170	+0.07

For the 18 cases in which the differences are at least 4 times their probable errors the results are:

	f	Absolute Values	Relative Values
Plus differences	12	+0.536	+ 5.73
Minus differences	6	−1.634	−10.93
All differences	18	−0.187	+ 0.17

These facts in a somewhat different form are made clear to the eye in Diagrams 1 and 2.[14]

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[14] Two types of graphs seem most suited to bring out clearly these results. In both, the signs and magnitudes of the differences between the normally developing and the eliminated series are shown by the direction and lengths of a series of lines. The solid lines falling below the zero bar show on the scale to the left the magnitude of the negative differences—*i. e.*, of those

The first of these graphs shows the values reduced to percentages of the constants for the general population of seeds from which the samples used in these experiments were drawn, *i. e.*, the constants given in Table X. The second shows the ratio of the differences to their probable errors.

The impression given by both of these charts is that the mean weight of the surviving seeds has been increased by the mortality, although there are one or two conspicuously large negative values in each case. This impression is borne out by the numerical result, if we confine our attention to the signs, merely. Of the 50 experiments, 29 show an increase and 21 a decrease in seed weight, whereas if there were no relationship between mean seed weight and viability, the deviations would be expected to be equally divided between positive and negative, except for the error of random sampling which would be given by $.6745\sqrt{50 \times .5 \times .5}$. Thus in the present case for the whole fifty experiments, the deviation from the equality which we should expect if there were no relationship between mean seed weight and mortality is 4 ± 2.38 series. Surely this can not be regarded as a trustworthy difference, but we note that the difference has the same sign and is relatively larger as we reduce our number of cases by disregarding those comparisons which are less

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in which the seeds failing were heavier or more variable than those which developed, in which selection decreased mean weight or variability. The broken lines extending above the zero bar show the number and the magnitude of the differences indicating an increase in mean or in variability as the result of selective elimination. The length of these bars may be determined in three different ways. They may simply represent the absolute differences (in units of .025 gram). They may represent percentage difference, on the basis of the constant for the whole population, as explained above. They may be in terms of the ratio of the difference to its probable error.

The first is the method used in the diagrams of the earlier paper. It is of no advantage here where the number of entries is too numerous to enable absolute values for individual series to be conveniently read from them. The second has the merit of presenting to the eye all the values in comparable terms. The third shows at a glance the statistical significance to be attached to the differences represented. The two latter are used.

probably statistically significant with respect to their probable errors. Thus if we throw out the 26 cases which are less than 2.5 times their probable error, we find that 15 are positive and 9 negative, a deviation of 3 ± 1.65.

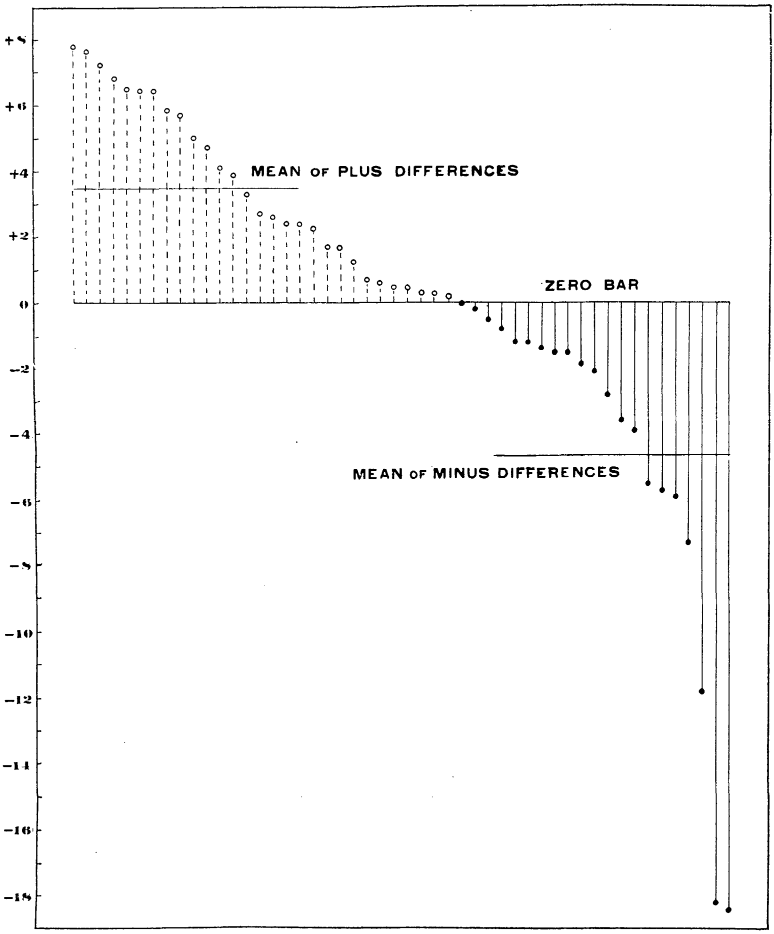

Diagram 1.

If we consider only differences which are four times their probable error, we find 12 positive and 6 negative, a deviation from equality of 3 ± 1.43.

When, however, we turn to the averages—both absolute and relative—we see very little support for the view that there is a tendency for the weight of surviving seeds to be heavier than those which fail. Sometimes, the general average is positive and sometimes it is negative in sign; it is always insignificant in magnitude. Nor, to return to the question of the more qualitative classification of the experiments, can any great weight be attached to such inequalities in the number of positive and negative differences as we have secured.

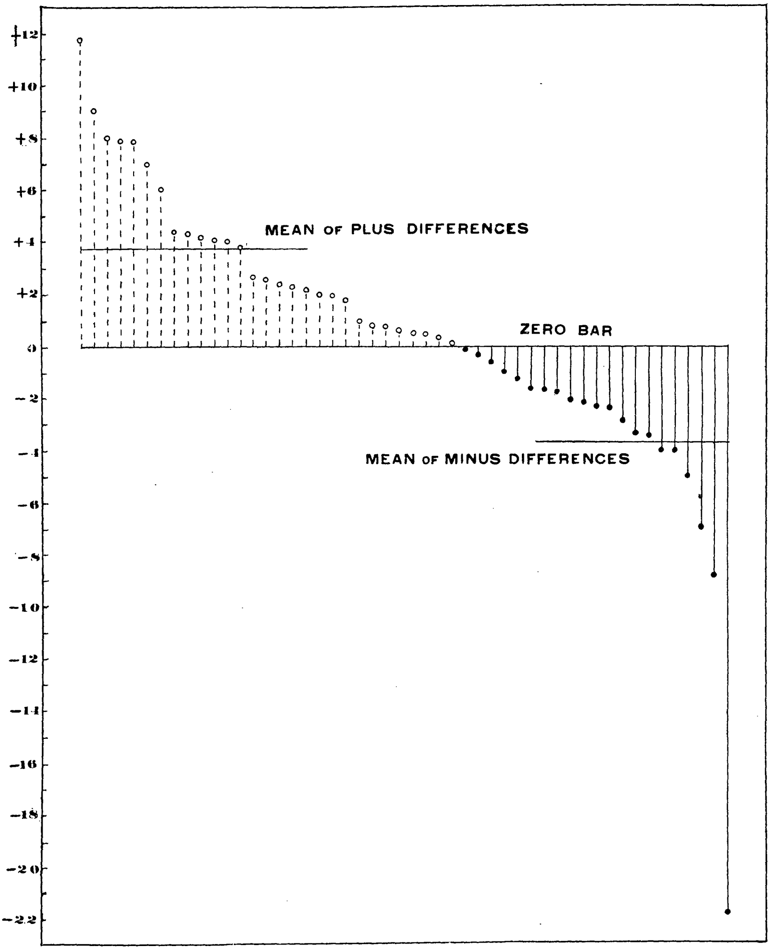

DIAGRAM 2.

The mean values of the ratios of the differences, *A–C,* to their probable errors have also been struck. The 21 negative cases give a mean ratio of 3.70 while the 29 positive values give 3.75. These substantial averages taken in connection with the number of rather high individual ratios certainly suggest that there are real biological differences between the samples of seeds. One expression of these differences is seen in the fact that in some cases the seeds which survive average heavier and in other cases lighter than in the population from which they were drawn.

Consider now the weight relations of seeds giving abnormal germinations and those failing to germinate, *B–C:*

	f	Absolute Values	Relative Values
Plus differences	32	+.581	+4.34
Minus differences	18	−.287	−2.08
All differences	50	+.268	+2.03

Thus there is a deviation from equality of 7 ± 2.38 cases, and this is probably significant.

For the abnormal germinations N is small; there are only 12 cases in which the difference is over 2.5 times its probable error. These are:

	f	Absolute Values	Relative Values
Plus differences	11	+1.026	+7.39
Minus differences	1	−0.450	−2.23
All differences	12	+0.903	+6.58

In seven series, diff. $E_{\text{diff.}} > 4$. *All these are positive;* they give a mean of 1.093 *absolute* and 8.47 *relative.*

Thus, apparently, the seeds which germinate abnormally are distinctly heavier than those which fail to germinate.

If now we combine A and B and compare all seeds which germinated with all those which failed, we have:

	f	Absolute Values	Relative Values
Plus differences	31	+0.360	+3.25
Minus differences	19	−0.513	−3.26
All differences	50	+0.028	+0.77

For the cases which are 2.5 or more times their probable error:

	f	Absolute Values	Relative Values
Plus differences	17	+0.510	+4.92
Minus differences	7	−1.035	−6.44
All differences	24	+0.060	+1.60

Thus by combining normal and abnormal germinations there is stronger evidence for an increase in mean seed weight by a selective death rate than when the normal germinations alone are considered. This point will be taken up again.

Just here it is necessary to point out that in this series merely the capacity for germination of the seeds in sand is taken into account, whereas in the former study only those were considered viable which had produced fertile plants. In combining normal and abnormal seedlings and contrasting them with those which failed to germinate at all, we are undoubtedly considerably overestimating the capacity for survival in nature.[15]

[15] From personal experience in the handling of the plants I have no doubt whatever that had germination taken place in a substratum less easily displaced than sand (*e. g.*, in a stiff clay soil) a number of the seeds classified as abnormal in germination would not have succeeded in unfolding their primordial leaves to the light. Again, I believe there is not the slightest question that of those which did reach the surface a higher proportion would fail to develop into mature plants than of the seedlings classified as normal. In fine, there is probably a post-germination as well as pre-germination mortality, and this mortality is probably selective. Indeed for morphological variations it has been shown to be so. (Harris, J. Arthur, "A Simple Demonstration of the Action of Natural Selection," *Science*, N. S., 36: 713–75. 1912). My general impression from working with the seedlings of both sorts is that there is likely to be a larger difference in mortality between the normal and abnormal seedlings of this paper than between the normal and abnormal seedlings of the study of the death rate of normal and morphologically aberrant seedlings.

It is possible, therefore, that such differences in mean weight as are found between the results of the two investigations may be in part due to a somewhat different elimination during germination and in part due to a selective mortality occurring beyond the point at which the census for the later series of experiments was necessarily closed. Thus it appears that when the abnormal germinations are grouped with the normal to give the comparison $(A + B) - C$ the evidence for an increase in mean seed weight through selective mortality of the lighter seeds is strengthened. A comparison of the two classes of seedlings also suggests that the seeds giving rise to those which are abnormal may be heavier than those germinating

Ideally, to obtain results valid for individuals attaining reproductive maturity one should take a small proportion of the seeds germinating normally and a much higher proportion of those giving rise to abnormal seedlings and combine them with the seeds failing to germinate. There is no possible way of estimating the proportion of A and B which should be classed with C. If one wishes to make the comparison which shall be at the opposite extreme of that in which all seeds germinating at all are compared with those failing to germinate, he may combine the seeds germinating abnormally with those which do not germinate. Thus $(A+B)-C$ and $A-(B+C)$ will give us the upper and lower possible measures of the influence of mortality of abnormal seedlings on seed weight.

Turning to the comparison of means for $A-(B+C)$:

	f	Absolute Values	Relative Values
Plus differences	27	+0.371	+3.46
Minus differences	23	−0.745	−4.81
All differences	50	−0.142	−0.35

Restricting comparisons to differences at least 2.5 times their probable error:

	f	Absolute Values	Relative Values
Plus differences	14	+0.524	+5.28
Minus differences	13	−1.192	−7.73
All differences	27	−0.302	−0.99

Or restricting still further to those which are at least $4E$:

	f	Absolute Values	Relative Values
Plus differences	12	+0.515	+ 5.46
Minus differences	8	−1.599	−10.64
All differences	20	−0.331	− 0.98

Certainly, there is in these figures no trustworthy indication of an increase of mean weight as a result of selective mortality.

normally. If this is true, and if the abnormal seedlings have a higher post-germination mortality, it is clear that some of the increase in mean observed in these experiments would have disappeared if the plants had been required to develop to maturity under field conditions.

Somewhere between this minimum value and the one given above by $(A+B)-C$ probably lies the true measure of the change in mean weight as it would occur if the plants were required (as they would be in nature) to grow to reproductive maturity.

I now turn to the individual varieties. This demands, for results which shall be at all trustworthy, the combination of both sets of experiments.[16]

The accompanying table gives the results for the relative differences in mean weight (differences expressed as percentages of the general population constant).

Varieties	f	Relative Values
NAVY:		
Plus differences	18	+2.461
Minus differences	6	−1.134
All differences	24	+1.562
NE PLUS ULTRA:		
Plus differences	5	+1.122
Minus differences	3	−1.962
All differences	8	−0.022
WHITE FLAGEOLET:		
Plus differences	9	+1.787
Minus differences	3	−0.247
All differences	12	+1.276
BURPEE'S STRINGLESS:		
Plus differences	10	+1.244
Minus differences	16	−1.048
All differences	26	−0.167
GOLDEN WAX:		
Plus differences	0	———
Minus differences	7	−2.087
All differences	7	−2.087
FLAGEOLET WAX:		
Plus differences	1	+0.263

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[16] The method of rendering the result of these sand cultures most nearly comparable with the field experiments is to draw the comparison between the germinated seed and the general population from which they were drawn. Of course, the errors of random sampling in the drawing of the seeds would be overcome by comparing the constants for the seeds actually planted $(A+B+C)$ with those failing to develop, but this would not give differences comparable with those from field culture work where $(A+B+C+\ldots)$, not $(A+B+C)$, is known.

Anyone who cares to do so may make this comparison numerically for the whole material by taking the physical constants for $(A+B)$ and subtracting from them the general population constants given in Table X. It has already been made graphically in a paper on "Current Progress in the Study of Natural Selection," in *Pop. Sci. Mo.*, in press.

I believe that the purely statistical differences between the two sets of

This anaylsis of means by varieties is most suggestive. Leaving out of account Flageolet Wax for which there is only a single experiment, it appears that in Navy and White Flageolet there is a distinct increase in mean weight of survivors, that in Ne Plus Ultra and Burpee's Stringless there is no marked change in mean weight, while in Golden Wax there is a pronounced tendency for the survivors to be lighter than the general population.[17]

It is clear that such a condition as this would give, with a proper combination of strains, precisely the general result that we have found for the means: that is, an average of no change by selective elimination but significantly positive differences in some experiments and significantly negative differences in others. Here is a problem requiring further analysis—which, however, can be profitably undertaken only when larger bodies of experimental evidence are at hand.

Comparison of Absolute Variabilities

For the standard deviations for seeds germinating normally and seeds failing to germinate, *A–C,* in the whole material the results are:

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experiments are not sufficient to be of material importance. Much greater weight is probably to be attached to certain experimental and biological factors. These are to be seen in both (*a*) the possible influence of the two types of substrata, and (*b*) the fact that in the field cultures viability was measured in terms of capacity to produce mature fertile plants, while in the sand cultures it was (necessarily) measured in terms of the capacity for (normal or abnormal) germination only.

[17] Possibly these results are due merely to the unavoidable errors of experiment and of sampling. Only far wider series of data can settle this point; until then no stress whatever is to be laid upon it. But *a priori* there is nothing unreasonable or improbable in such results. These varieties differ widely in the characteristics of their seeds and there is nothing surprising in the indication that in one variety the death rate is more concentrated toward the lower end of the range of variation, in another it is more restricted to the upper limit, while in a third both extremes are decimated. This seems especially probable in view of the fact that in this as in other cultivated species the varieties have been developed to suit the fancy of man and not to meet the requirements of the race in competitive life in nature.

	f	Absolute Values	Relative Values
Plus differences	17	+.145	+ 8.67
Minus differences	33	−.351	−13.77
All differences	50	−.183	− 6.14

These relationships are made clear by Diagrams 3 and 4. The first of these shows the differences in standard deviations expressed as percentages of the population S.D. The second shows the ratio of the differences to their probable errors.

The distribution of the differences which are at least 2.5 times their probable errors may be summarized:

	f	Absolute Values	Relative Values
Plus differences	5	+.335	+21.81
Minus differences	15	−.569	−21.64
All differences	20	−.343	−10.78

Thus of the 17 positive differences, 12 or about 71 per cent. are statistically untrustworthy (*i. e.*, $< 2.5E$) while

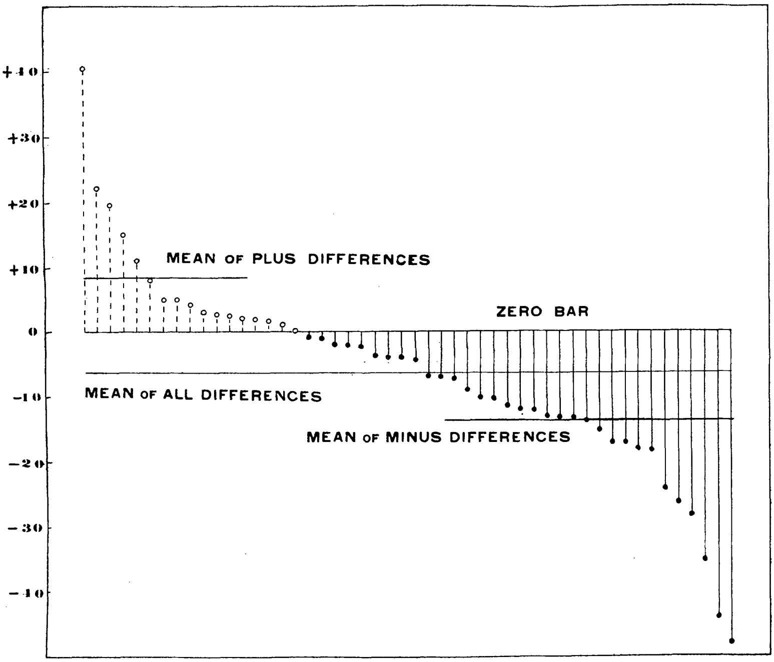

DIAGRAM 3.

of the 33 negative differences, only 18 or roughly 55 per cent. are not statistically significant. The deviations from equality are 8 ± 2.38 for the whole material and 5 ± 1.51 for the 20 series which are more probably statistically significant.

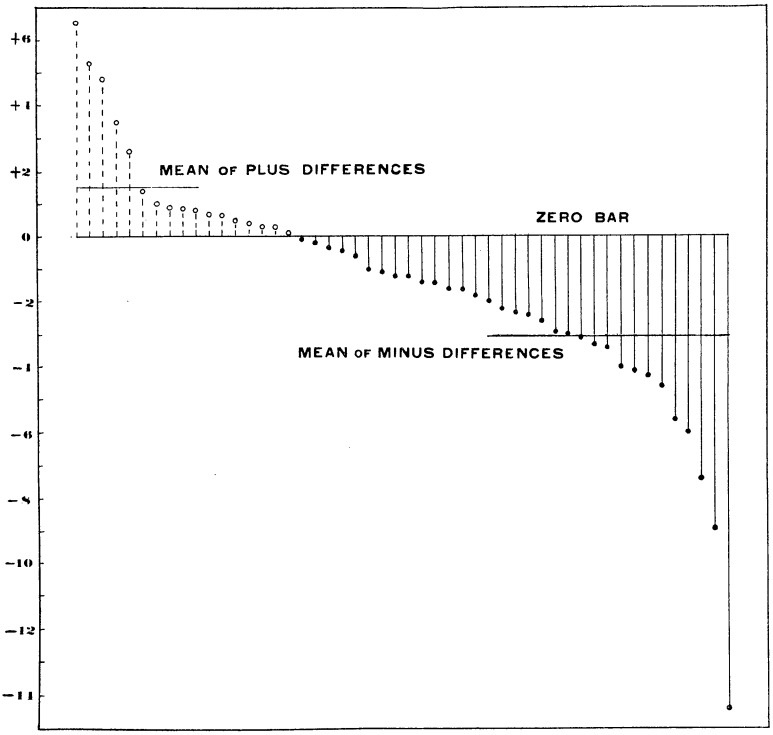

Diagram 4.

Only 12 individual differences are over four times their probable error:

	f	Absolute Values	Relative Values
Plus differences............	3	+.363	+25.22
Minus differences..........	9	−.769	−27.31
All differences.............	12	−.486	−14.18

These results can leave no doubt as to the reduction in the absolute variability when the seeds which produce normal seedlings are selected out from those which fail to develop. The number of negative differences is significantly higher than the number of positive differences. The mean of the negative differences is larger numerically than that of the positive differences. The proportion of negative differences is higher among the constants which are more probably trustworthy, being only 1.5:1 among those $< 2.5E$ but 3:1 among those $> 2.5E$. The average ratio of the difference to its probable error is only 1.65 for the positive differences, but reaches 3.04 for those which are negative in sign.

Thus these results are in excellent agreement with those of the field experiments.

Turn now to the same question with regard to the seeds giving abnormal germinations, *B–C:*

	f	Absolute Values	Relative Values
Plus differences	23	+.235	+12.14
Minus differences	27	−.331	−15.32
All differences	50	−.071	− 2.69

For those differences at least 2.5 times their probable error, the results are:

	f	Absolute Values	Relative Values
Plus differences	3	+.466	+28.14
Minus differences	11	−.501	−21.75
All differences	14	−.294	−11.06

Perhaps the evidence for a reduction in variability is not so strong when seeds germinating abnormally are compared with those not germinating at all. This is precisely what one would expect if such seeds may be regarded as in some degree intermediate between those which produce perfect seedlings and those which produce no seedlings at all.

I now turn to the question of a possible reduction in variability as one passes from seeds germinating abnormally to those germinating normally. The answer is given by the comparison *A–B:*

	f	Absolute Values	Relative Values
Plus differences	19	+.273	+13.78
Minus differences	31	−.366	−15.95
All differences	50	−.123	− 4.66

For differences 2.5 or more times their probable errors:

	f	Absolute Values	Relative Values
Plus differences	6	+.505	+24.41
Minus differences	9	−.560	−25.08
All differences	15	−.134	− 5.29

It is clear that in passing from the seeds producing abnormal seedlings to those germinating normally there is in general a reduction in absolute variability of weight. This point will be discussed in greater detail when relative variabilities are taken up.

If now the comparisons be drawn between all seeds which germinate (whether normally or abnormally) and those which do not germinate at all, *i. e.*, $(A+B)-C$, we have:

	f	Absolute Values	Relative Values
Plus differences	15	+.136	+ 8.37
Minus differences	35	−.266	−11.18
All differences	50	−.146	− 5.32

Or restricting the comparison as usual to those which are more probably statistically trustworthy ($>2.5E$):

	f	Absolute Values	Relative Values
Plus differences	4	+.297	+20.85
Minus differences	13	−.475	−19.12
All differences	17	−.294	− 9.72

The comparison involving the other extreme in the treatment of the abnormal seedlings is $A-(B+C)$. For all the series this gives:

	f	Absolute Values	Relative Values
Plus differences	17	+.160	+ 9.13
Minus differences	33	−.331	−13.45
All differences	50	−.164	− 5.77

For cases at least 2.5*E*, the results are:

	f	Absolute Values	Relative Values
Plus differences	5	+.352	+22.21
Minus differences	16	−.521	−20.26
All differences	21	−.312	−10.15

Thus the treatment of the abnormal germinations does not materially affect the general results for reduction in variability.

It seems unnecessary to consider both absolute and relative variabilities for the individual varieties. The results will be summarized for the coefficients of variation.

COMPARISON OF RELATIVE VARIABILITIES

As demonstrated in the preceding sections, mortality is so related to seed weight that absolute variability is reduced in passing from seeds which fail to germinate to those which produce seedlings. Possibly, too, there is a change in type. Such changes in mean, even if due only to the errors of sampling, may somewhat affect absolute variabilities. It is desirable, therefore, to reduce all these to relative terms—to express them as ratios of the absolute variabilities (× 100) to the means.

The coefficients of variation, being already in relative terms, give only one set of means to consider.

For *A–C*, all series, the results are:

	f	Averages
Plus differences	12	+1.45
Minus differences	38	−1.95
All differences	50	−1.13

Thus we have a deviation from the 25:25 ratio of 13 ± 2.38 which must certainly be regarded as significant.

For cases at least 2.5 times their probable error:

	f	Averages
Plus differences	3	+3.45
Minus differences	16	−3.26
All differences	19	−2.22

Only 8 are 4 or more times their probable error. Of these, 3 are positive, averaging + 3.34, while 5 are negative, averaging —4.45.

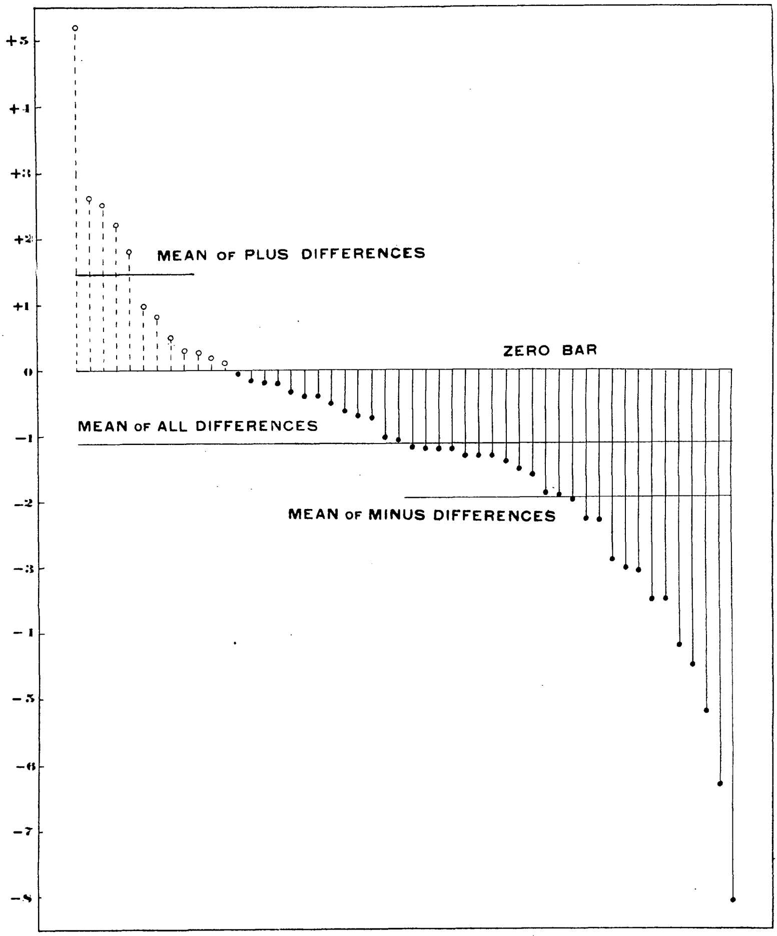

DIAGRAM 5.

The differences for *A–C,* all material, are shown in Diagram 5. Note by comparison with Diagrams 3 and 4 that the evidence for selective mortality becomes stronger when variabilities corrected for size of the means are substituted for absolute values.

Comparison of the relative variability in weight of seeds giving abnormal germinations with that of those failing to germinate at all, *B–C*, gives:

	f	Averages
Plus differences..................	18	+2.24
Minus differences................	32	−2.35
All differences...................	50	−0.70

Restricting comparisons to differences at least $2.5E$:

	f	Averages
Plus differences..................	2	+5.47
Minus differences................	10	−4.74
All differences...................	12	−3.04

Differences at least $4E$ are:

	f	Averages
Plus differences..................	1	+6.17
Minus differences................	6	−4.56
All differences...................	7	−3.03

The reduction in variability in passing from *C* to *B* is clearly significant.

Consider now the difference between seeds germinating abnormally and those germinating normally, *A–B*:

	f	Averages
Plus differences..................	21	+2.11
Minus differences................	29	−2.27
All differences...................	50	−0.43

Or taking the usual minimum standard of statistical significance:

	f	Averages
Plus differences..................	7	+3.42
Minus differences................	5	−5.32
All differences...................	12	−0.23

There is no certainty of any reduction in relative variability here. But turning back to the standard deviations we find that there were fair indications of a lowering of variability.

This apparently contradictory result finds an explanation when the means are taken more fully into account. Consider these, *A–B:*

	f	Absolute Values	Relative Values
Plus differences	23	+.331	+2.96
Minus differences	27	−.899	−5.96
All differences	50	−.333	−1.86

Restricting to those at least 2.5*E:*

	f	Absolute Values	Relative Values
Plus differences	6	+0.596	+ 5.43
Minus differences	12	−1.703	−11.02
All differences	18	−0.937	− 5.54

The mean weights are higher in series *B* than in series *A*. *The relative variabilities for B are, therefore, reduced by the higher values of the means.* Thus when we take the comparison *A–B* for relative variabilities, the reduction which we noted in dealing with the absolute values does not appear.

Consider now the result of combining all seeds which germinated at all (whether normally or abnormally) and comparing their coefficients of variation with those of the seeds which failed to germinate, $(A+B)-C$:

	f	Averages
Plus differences	12	+1.29
Minus differences	38	−1.71
All differences	50	−0.99

Or restricting to differences at least 2.5*E:*

	f	Averages
Plus differences	4	+2.74
Minus differences	13	−2.69
All differences	17	−1.41

Thus we have for all the material a deviation of 13 ± 2.38 cases from the equality to be expected if there were no selective mortality tending to reduce variability. In 38 cases out of 50 the variability of the seeds which germinated is lower than that of those which failed.

In this comparison, all seeds which germinate at all have been considered viable—although it is practically certain that many of the abnormal ones would not have been able to reach maturity. If one wishes to take the other extreme, he may throw all the seeds producing abnormal seedlings with those which failed to germinate at all and compare with those germinating in a perfectly normal manner, $A - (B + C)$.

	f	Averages
Plus differences	12	+1.52
Minus differences	38	−1.69
All differences	50	−0.92

Or for differences $> 2.5E$:

	f	Averages
Plus differences	4	+3.13
Minus differences	16	−2.65
All differences	20	−1.49

Thus the disposition of the abnormal seedlings makes relatively little difference in the end result.

Variety	*f*	Mean Difference
Navy:		
Plus differences	9	+1.253
Minus differences	15	−0.796
All differences	24	−0.028
Ne Plus Ultra:		
Plus differences	4	+0.878
Minus differences	4	−1.833
All differences	8	−0.478
White Flageolet:		
Plus differences	2	+0.031
Minus differences	10	−0.683
All differences	12	−0.563
Burpee's Stringless:		
Plus differences	3	+0.637
Minus differences	23	−0.669
All differences	26	−0.518
Golden Wax:		
Plus differences	1	+0.175
Minus differences	6	−1.356
All differences	7	−1.137
Flageolet Wax:		
Minus differences	1	−0.283

I now combine the differences $(A + B) - (A + B + C + \cdot \cdot \cdot)$ for the 50 experiments of the present paper with the 28 given by the field test, as already done for the relative means. The little table gives the results.

For every variety except Ne Plus Ultra the differences are exclusively or preponderantly negative. For each of the six varieties the general average is negative in sign, although sometimes very low. Such results give additional force to the conclusion that there is a reduction in variability due to a differential mortality.

V. Recapitulation and Discussion

1. This paper embodies a portion of the data of a second study of the relationship between seed weight and seed viability in *Phaseolus vulgaris*. The constants are based on greenhouse plantings in sand of some 46,000 individually weighed seeds, chiefly of the pedigrees employed in the field experiments.

Bearing in mind the various sources of error sufficiently emphasized in the body of the paper, the following may be said of the findings.

2. In general the results of the first study are fully confirmed. In certain particulars, however, the narrower analysis made possible by the wider materials now available suggests some modification and considerable extension of conclusions.

3. The statement concerning means was:

> This selective death rate is of such a nature that the mean of the available seeds remains practically the same as that of the original populations, while the variability is reduced. In short, both large and small seeds are less capable of developing into fertile plants than are those which do not deviate so widely above or below the type.

This was all that could then be said, for while many thousands of individually weighed seeds were involved, the number of series was too low to justify analysis into the individual varieties or into groups by age of seed or conditions of growth. Examined in the same manner, these data show *in the long run* some indication of an increase in the mean weight of the survivors, but no uncontrovertible evidence of a change in mean weight as a result of selective mortality. But *individually considered*, more differences in mean weight are from two to four or more times their probable errors than can possibly be attributed to experimental or sampling errors. Some of these differences are positive, others are negative. There seems in view of these facts, no escape from the conclusion that there is a real biological relationship between weight and viability of such a nature that in some experiments the heavier and in other experiments the lighter seeds are most heavily drawn upon in the mortality. This seems clear from the greenhouse experiments in whatever way the differences are taken. There are indications of the same condition in field cultures, although here the criterion of statistical trustworthiness is, because of the dual errors of sampling, less dependable.

There is strong evidence for varietal differences with respect to mortality. In some strains the heavier, in others the lighter, seeds seem less capable of development. The reason for these differences may be sought in the inherent characters of the stocks used or in the environments to which they have been subjected. This question is, however, so complicated that larger and more diverse series of data must be gotten together for its final solution.

4. Consider now the variabilities. There can be no question whatever concerning the reality of the reduction in variability, either absolute or relative, as a result of differential mortality. The following conditions seem to prevail for the individual comparisons which may be made.

There is probably a reduction in absolute variability, and there is certainly a reduction in relative variability, in passing from seeds which fail to germinate to those which produce abnormal seedlings.

There is probably also a reduction in standard deviation in weight in passing from seeds which give abnormal seedlings to those which germinate normally. This reduction is not so evident in the coefficients of variation, probably because of changes occurring in mean weight.

There is clearly a lowering of both absolute and relative variabilities between seeds which fail to germinate and those which germinate normally, or those which germinate at all, either abnormally or normally. The disposition which is made of the seeds which give rise to abnormal seedlings does not affect the conclusion concerning a reduction in variability due to a differential death rate.

To what extent this reduction is incidental to a change in mean through elimination preponderantly from one end of the range, as compared with elimination from both the extremes without change of type, must be determined on wider series of data, and probably by the use of statistical methods not yet applied to the problem.

5. The constants of this paper, taken in connection with data made directly available from other published studies by the key letters, can be used towards the solution of a number of problems not touched upon here. These have been purposely left out of account because they were aside from the present main purpose and because I hope to have much more extensive materials for their solution later.

6. Concerning the causes of the differences in viability no conclusions can be drawn. I have shown[18] that in general the larger seeds require longer for germination, but the precise relation, if any, of this phenomenon to selective mortality, as well as its explanation in more general physical and chemical terms, are still to be worked out.

TUMAMOC HILL, TUCSON, ARIZ.,
April 3, 1913

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[18] Harris, J. Arthur, ''A First Study of the Relationship between the Weight of the Bean Seed, *Phaseolus vulgaris*, and the Time Required for its Germination.'' In press.